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ABSTRACT

This document is the product of working groups of representatives from industry, business, associations, labor, and education who studied the types and levels of occupational competencies necessary for entry and sustained productive employment in the chemistry-based technology industry and in agribusiness. Representatives of both industries suggested these actions: (1) teach elementary school students to be competent in the basic skills of reading, writing, math, and science and encourage high school students to become proficient in oral and written communications, math, and science; (2) recruit young people into these occupational fields and increase public awareness of them; (3) enhance the image of vocational-technical education; (4) keep vocational-technical instructors current with the industry; (5) develop cooperative education programs; (6) write sequential curriculum for secondary and postsecondary education vocational programs; (7) develop models for competency-based education that includes academic as well as vocational skills; (8) provide exemplary vocational-technical education facilities; (9) employers and educators cooperatively develop a list of occupational competencies and design methods of certification; (10) develop affordable and accessible continuing education materials; (11) survey employers to gather information on job markets, human capital demands, and educational needs for the next 10 years; and (12) follow through on student placement and job performance. The document's section on agribusiness includes information on a definition and description of the field, educational requirements, employment opportunities, personal and job skills, equipment and materials, publications, and a summary of key issues to address. Information on similar topics are provided in the section on chemistry-based technology. The names and addresses of agribusiness and chemistry-based technology working group members and the National Council on Vocational Education are also provided. (CML)

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Occupational Competencies

A Study of the
Vocational-Technical Education Needs of the
Agribusiness and Chemistry-Based Technology Industries

Conducted by Two Working Groups of
Industrial, Business, and Educational Representatives

Under the Auspices of
The National Council on Vocational Education

January 1990

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Preface

The National Council on Vocational Education deeply appreciates the support and assistance of the more than 50 individuals who served on the two working groups studying the educational requirements for vocational-technical programs in the fields of agribusiness and chemistry-based technology. Their knowledge and insight made this report possible.

The provision for such studies, contained in the Carl Perkins Act of 1984, offers an opportunity for National Council members and staff to discuss the present and future personnel needs of industry with key representatives of those businesses. After these discussions, the National Council can communicate to educators what will be necessary for students and employees to learn to meet the needs of these industries.

This report will be used by state and local advisors and administrators to help in determining the relevance and quality of vocational-technical education programs. The National Council on Vocational Education continues to support the important, mutually beneficial relationship between business/industry/labor and vocational-technical education. Secondary and post-secondary programs benefit from close, working relationships with business, industry, and labor. At the same time, vocational-technical education programs provide students with an introduction to career occupations and the opportunities to progress up a career ladder.

Members and staff of the National Council welcome comments and suggestions from representatives of business, industry, and labor on industries that should be studied by subsequent working groups.

With these cooperative efforts, America will have the best and most effective vocational-technical education system, which will help support the lifelong learning its workforce needs.

Committee Chairpersons
Pat Silversmith
Sydney Duberstein

Foreword

Like a giant cogwheel that is out of sync with its gear, the United States is facing a mismatch between the jobs that need doing and the workers who can do them.

Two decades ago the talk was of retooling American industrial plants to increase productivity and harness technology. Today, the talk is of retooling the American workforce by focusing on vocational-technical education programs, elementary and secondary schools, and attitudes about work.

This retooling of the American workforce means that people will have to learn to think and to learn to communicate more effectively than ever before. They will have to be able to do so with flexibility to match the rapidly changing demands made on them by the workplace of the future. Workers will have to learn how to adapt in a constantly changing and evolving job, and they will have to do it the rest of their employed lives.

From now on, a strong basic education, followed by more education, training and retraining, will become an accepted part of our lifetime work regime.

Unless the powers of this country – Federal, State, and private enterprise – do something to encourage the recruitment and training of competent, qualified workers for the jobs that need doing, our position in the world marketplace will be seriously, and for the long-term, jeopardized. All the efforts directed toward boosting technology and productivity, long the goal of American policymakers, could be at risk in the massive failure to match competent workers to the jobs that keep the economy running.

This report is designed to help vocational-technical educators and administrators, business, industry, and labor protect the human-capital assets in the fields of agribusiness and chemistry-based technology industries by looking at what will be required of workers in those industries in the next decade. We looked at the skills needed, first, to enter vocational-technical education, those needed when the program is completed, and finally, those needed to advance up the career ladder.

We hope to offer insights into the changing requirements of employers and the level of competency workers must possess to meet those needs.

We chose the agribusiness and chemistry-based technology industries for this study because they have demonstrated need for technical expertise that can be generated through vocational-technical education programs. The demand for employees in these fields is far outreaching the supply, and without active recruitment and serious educational focus, these fields will face a critical shortage of human capital in the next decade.

At the same time that these businesses and industries are growing, the population and workforce are growing more slowly than at any time since the 1930s. The pool of young workers entering the labor market is drying up into a labor puddle. The competition for qualified workers to fill the jobs in these industries will be intense.

The Bureau of Labor Statistics predicts that by the year 2000, 80 percent of the available jobs will require some kind of after-high school education. Of those jobs, 80 percent will require something other than, or in addition to, a traditional liberal arts education.

In the future, nearly 4 percent of all workers will be in some kind of continuing education or on-the-job training program each year.

The implications? More workers—those new to the workforce as well as those retraining or adding skills—will need more education, and the burden will fall increasingly to vocational-technical institutions.

At the same time that our workforce is learning job-specific skills, they also must be equipped to meet changes. They must learn about decision-making, problem solving, creativity, communications, critical thinking, evaluation, analysis, how to consider several ideas at once and arrive at a conclusion, and cooperative teamwork. These are the skills that enable workers to turn jobs into careers.

In order to become successful employees, our students must be taught to understand what working for a living is, and they must become acquainted with occupational choices. In addition to practical application skills, students need to establish a positive work attitude and a solid work ethic. They need reasoning skills and enough curiosity to put the skills to work.

In our research for this report, we discovered numerous needs.

- **Educators are asking employers** to agree on a list of job-skill competencies required of entry-level employees so that curricula can be developed to reflect those needs.

- **Educators are asking industrial representatives** to help keep them current on technology and job requirements, so they will be qualified to teach students relevant skills.

- **Employers are asking educators** to teach students how to add, subtract, divide, multiply, and compute with basic, standard mathematical procedures; how to draw a logical conclusion by applying basic scientific facts using the scientific method; how to communicate, both orally and in writing, using good grammar and clear, concise expression; and how to read well enough to comprehend directions.

- **Employers are asking that parents and guidance counselors** keep an open mind when introducing students to career options and that they not deny the vocational-technical opportunities to bright, qualified students.

- **Employers want graduates who are inquisitive,** on-time, courteous, honest, conscientious, and competent in the basic skills necessary to learn specific job requirements.

We hope this report will help facilitate some of the changes needed to meet these needs.

Contents

Introduction

Mandate of the Carl Perkins Act of 1984

Part D of the Carl Perkins Act of 1984 authorizes the National Council on Vocational Education to establish working groups that comprise representatives from industry, business, associations, labor, and education to study the occupational competencies needed for selected industries. The purpose of these working groups is to provide the President, the Secretary of Education, members of Congress, and State and local education administrators and advisors with current information on the types and levels of competencies necessary for entry and sustained productive employment in given jobs or industries.

Discussions with these key representatives have provided information about the kinds of employment available to vocational-technical education program graduates, the academic background needed to complete a vocational-technical program, the job skills required, the equipment used in the industry, the facilities required to teach the skills, and the educational materials available in the subject area.

The Carl Perkins Act gives the National Council the authority to establish working groups to study the occupations National Council members and staff consider important or necessary. Members of the working groups are appointed by the National Council on the advice of national trade and professional associations, key industry representatives, and labor organizations. Working group members are chosen for their specific knowledge of the technology and practice of the occupations they represent. The results and recommendations of the working groups are disseminated to each State Council on Vocational Education, appropriate state agencies, and local leaders.

The Carl Perkins Act also gives the states a mandate similar to the occupational competency mandate given to the National Council. While the National Council looks at the overall trends, state technical committees look at curriculum and specific competencies taught. The role of the technical committees is to advise the state councils and the state boards on the development of model curricula to address state labor-market needs.

Methods and Procedures

Members and staff of the National Council on Vocational Education, under the leadership of Pat Silversmith and Sydney Duberstein, met May 2 and 3, 1989, in Washington, D.C., with representatives of national trade associations, business, industry, labor, and educators involved in the many various aspects of agribusiness and chemistry-based technology. During the meetings, the representatives discussed future occupational competencies for their employment areas, the educational background that will be necessary to prepare students to accomplish those jobs, and strategy for attracting young people to careers in these occupations.

Draft reports on each industry reflecting discussions from those meetings were widely circulated. Numerous, extensive comments were received from other key industry representatives and educators. This final report reflects these comments, in addition to the ideas discussed at the meetings.

Lists of all the participants at the May 2 and 3 meetings, as well as others who made comments on the draft reports, are in Appendix I and II.

Summary of Findings

The working groups met separately, and the draft reports were circulated independently of each other. It is interesting to note, however, that the recommendations of both groups were strikingly similar. They concluded that potential employees who graduate from vocational-technical education programs should have at least:

(1) high-school-level skills in math, science, communication, and use of computers;

(2) a core of occupational skills necessary for entry-level jobs, with job-specific skills to be provided through on-the-job training; and

(3) a strong work ethic and positive work attitude, plus an acknowledgment that learning is a lifelong process.

The working groups concluded that the educational system should be able to provide instruction to develop these skills and characteristics to help the United States be responsive to the needs of this high-technology, service-oriented society and to be competitive in world trade.

If employees are prepared with basic, transferable skills, then business, industry, and labor can provide additional job-specific, specialized education and training. In particular, smaller businesses need to be able to rely on the education system—both secondary and post-secondary—to provide students with a core of basic knowledge and skills. While smaller businesses can provide experience for recent vocational-technical education graduates, who often later become employees of larger companies, they do not have the resources to provide basic education and training.

Members of the working groups stated that mutually beneficial, cooperative efforts between business, industry, labor, and education should be encouraged. Business and industry need assistance retraining current employees. Customized training, available through several vocational-technical education programs, was commended.

Members of both working groups expressed serious concern over the increasing need for competent employees and the shrinking labor pool. Members discussed effective recruitment tactics and the need to spark students' interest early. Further, members urged that parents, educators, and guidance counselors not block students' interest in vocational-technical education but instead offer it as a way to expand opportunities.

Section I: Agribusiness

Agribusiness is a growing industry that is experiencing a shortage of qualified workers. According to the Midwest Research Institute, agribusiness is defined as: "The complex of economic activity which is created and maintained by the existence of farming and ranching operations."

The definition includes firms that sell services and supplies directly to farms, farm production operations, and firms that purchase farm and forest products for storage, processing, and distribution. Agribusiness is the economic activity, one link removed from basic farm production on both the input and output sides of the food and fiber sector of the economy.

A recent report from the National Agribusiness Education Commission defined agribusiness as including:

> *(1) businesses that provide supplies and services to farms and ranches; (2) businesses that market and process commodities from these producers of food and fiber; (3) the agricultural producers themselves, who are often significant businesses in their own right, and, at the other end of the chain; and (4) consumers.*

Working-group member Don Margenthaler, manager of community relations and international communications with Deere & Company, suggested that agribusiness is also: "The decision-making process used to manage an agricultural business on a daily basis."

Since American agribusiness is an important part of the new international economy, secondary and post-secondary vocational-technical education curricula must incorporate a global perspective to prepare employees for the highly competitive nature of production, business, and trade.

Future jobs in agribusiness will reflect technological changes and the vast amounts of information needed to sustain progress in the industry. Computer literacy will be a must. Management specialists will be as common on the farm as tractors. As food production has required less labor, time, and effort (although definitely not less education), there has been a gradual shift from a direct emphasis on farmers to an emphasis on the preparation of employees who make the farmer's job more profitable and efficient. The demand for qualified, well-educated employees in the support-service occupations will not decrease, as the demand for farmers has. Instead, this demand will increase. At the same time that the demand for agribusiness employees is increasing, other industries are experiencing similar needs. And all are drawing from the same shrinking labor pool. The competition for competent, well-educated, well-trained, motivated employees is intense.

Agriculture and agribusiness-related occupations now account for 1/5 of all employment. Agribusiness must be an integral part of education in agriculture. This report accurately describes the current and future vocational-technical education needs of the agribusiness community.

Ron Treiber
Owner/Manager, Cache LaPoudre Feeds and Farming
LaPorte, Colorado

Current jobs in production agriculture, forestry, and fisheries number approximately 4,480,000. Projected new jobs to the year 2000 show a loss of 538,000 in these occupations (a net loss of 12 percent). On the other hand, the support-service occupations are expected to grow dramatically in that same period—management, 39 percent; marketing and sales, 39 percent; technicians, 44 percent; mechanics, installers, and repairers, 23 percent; transportation and heavy-equipment operators, 16 percent; natural, computer, and mathematical scientists, 68 percent; and paraprofessionals, 43 percent.

Much of the burden to educate these employees will fall to the public education vocational-technical programs from the secondary level through post-secondary levels. Educators must prepare now to handle the demands on their programs and institutions in order to secure the United States' world market position and its standing in the delicate balance of the world economy.

Agribusiness Today

The agribusiness industry includes input and output business activities (with food and fiber production falling between the two), including agricultural suppliers (fertilizer, chemicals, and equipment manufacturing), service institutions (financial, insurance, and communications entities), marketing activities (transportation, processing, wholesaling, and retail units), and public service activities (market reporting, grades and standards, and weather information).

Economics—both national and global—has influenced the nature of agribusiness. No longer are farms and ranches self-contained and independent as they were in colonial times. Now they are interdependent, interrelated systems of production, processing, and distribution for food, fiber, and related products and services.

Today, agriculture is this nation's largest employer. According to the 1988 Fact Book of Agriculture, published by the U.S. Department of Agriculture, "about 21 million people work in some phase of agriculture – from growing food and fiber to selling it at the supermarket."

Maintaining the economic balance of the food and fiber agricultural system today is extremely complex, and depends on natural resources, the laws of nature, and technology. Furthermore, the economic well being of the United States agribusiness industry is governed, to a large extent, by its ability to compete in an international marketplace. Rapid development and adoption of technology are necessary to maintain or gain advantage in the worldwide economic competition.

Educational Requirements for an Agribusiness Career

Agribusiness offers demanding technical careers that require academic education, vocational-technical education, and practical experience. Educational requirements for jobs in agribusiness are increasing, especially in the areas of science, business, economics, accounting, and veterinary technology.

Several factors are influencing this need for more education. The organizational and technological complexity of the industry has increased, making fewer unskilled entry-level occupational opportunities available for high-school graduates. However, academic requirements for graduation have increased, allowing less time for students to enroll in vocational-technical programs at the secondary level.

Academic subjects that members of the working group recommend as a background for a career in agribusiness include: language arts, mathematics, accounting, economics, social science, biological and physical sciences. Specifically recommended for students entering secondary vocational-technical programs are chemistry, biology, environmental science, algebra, general and business economics, and communications, including the use of computers.

To integrate these concepts and principles effectively, two and preferably four years of vocational-technical agriscience and agribusiness must be part of the comprehensive high school program of study.

Beyond those basics, members recommend a combination of continuing, sequential post-secondary vocational-technical education courses over two to three years, with an absolute minimum of one year. For careers in agribusiness, advanced educational courses and continuing education courses are necessary. Some of these courses include agricultural economics – both macro- and microeconomics, agricultural business management (which considers aspects other than economics), at least two years of introductory agricultural sciences and principles of farming, keyboarding, and computer applications, and additional advanced agricultural and vocational-technical courses related to specific occupations, such as animal science, row-crop production, integrated pest management, irrigation technology, or veterinary technology.

Working group members urged educators and program curricula writers to establish a series of sequential courses so that students can be given credit for previous courses to avoid duplication of course material from level to level. Members also urged that academic credit toward high school graduation be given to students for math and science skills learned in vocational-technical education courses.

No one institution is identified as the major educator for agribusiness employees. Some occupations require college and university educations. Others can be filled from specific vocational-technical programs in high schools, community colleges, and vocational-technical schools. More advanced occupations in the agribusiness industry requiring degrees from community colleges and four-year institutions are taken in a sequence of two years of high school plus two years of post-secondary education (2 + 2, which results in a degree such as an A.A.S.) or two years of high school, two years of post-secondary education, plus two years of university-level study (2 + 2 + 2, which results in a B.S. or B.A. degree).

Judy Lawrence, coordinator of the animal-health technology project at the University of California's Davis campus, is helping develop a program of studies for graduates from secondary school animal-health programs with a similar specialized higher education curriculum, which does not exist now. According to Ms. Lawrence,

> *We have about 1,500 students statewide in secondary programs, and we need to provide them with some form of sequential education course. The agribusiness industry needs about 1,500 paravets (animal-health technicians) a year in California, as a conservative estimate. Jobs for these technicians go begging because we don't have enough graduates.*

Several working group members said there is a growing gap between current public vocational-technical education programs and the needs of agribusiness employers. In general, the programs are not keeping up with changes in technology and society. Admittedly, vocational-technical education is capital intensive and expensive for schools. This makes it tough to keep teachers and equipment current.

Computers and related technologies will be of increasing importance to the agribusiness industry.

John F. Burns
Executive Director
Association of Agricultural Computing Companies
Claytonville, Illinois

Educators and industry leaders emphasize the need for both academic studies and long-term exposure to actual agricultural experience. Growing up on a farm, participating in groups like the National FFA Organization (formerly Future Farmers of America) and 4-H, and studying vocational-technical programs in high school provide excellent exposure to the myriad of occupational careers available in agribusiness. What many people would call farm intuition – how to sense when something is right or wrong – comes from this lifelong exposure to agriculture. Knowing what to do and how to prevent problems before they happen, comes through education and experience.

Increasingly, people without a background in agriculture are finding employment in the large, diversified agribusiness industry. Not all computer operators know about production agriculture, but most agribusiness operations need the benefit of electronic data processing. Obviously, computer operators who are required to figure milk production costs will be a step ahead of their peers if they also know something about the nature of the milk producer — the cow.

One of the keys to successful vocational-technical education programs is direct, hands-on experience in the field. Cooperative education, where students spend part of the day in the classroom and part of the day in an actual work situation, is a good way to prepare students for real life situations on the job. Through cooperative education, students receive both academic and job skills.

Continuing education courses are useful, and indeed are becoming essential, for employees in agribusiness. All working group members urged that such courses be made available and kept affordable, and that materials to support them be developed. Topic areas in which continuing education is particularly useful include business, finance, and new technologies related to plant and animal production, and machinery development and operation.

Educational programs for agribusiness students need to provide cross-training for students to avoid too narrow a focus. Working group members expressed concern that students need to be able to do more than one job, and that they need to be familiar with equipment used in several operations.

Few private or specialized vocational-technical schools exist that can provide education for agribusiness. Some specialty schools for specific occupations do exist, and these may have better means of obtaining good teachers and equipment, and they may include more cooperative education; however, the bulk of the responsibility for educating future agribusiness employees falls to the public education system.

While no formal apprenticeship training programs exist for agribusiness employees, working group members strongly suggested that development of such programs be explored. In reality, cooperative education, secondary vocational-technical agriculture programs with supervised occupational experience, and other on-the-job training arrangements and internships take the place of formal apprenticeship programs.

Employment Opportunities

If the United States is to maintain its leading role in world food production, it must have an adequate supply of well-educated agribusiness specialists. Although fewer people are required to participate directly in production, the demand for people who can provide farmers with technical advice and services continues to grow.

From 1930 to 1974, some 33 million people left the farming industry. The farm population, which stood at 15 percent of the total United States population only three decades ago, is now down to 2 percent; however, the number of young people reaching working age on farms still exceeds the number of replacement farmers needed.

The critical area for agricultural employment lies one step beyond the farmers themselves. The number of necessary support-service employees is rising steadily, and the labor pool from which they are drawn is being tapped by many other industries as well — health care, construction, electronics, food service, automated offices, and so forth. This labor pool rapidly is becoming a labor puddle, and the squeeze surely will affect the agribusiness industry.

The categories of occupations for agribusiness employees with a vocational-technical education are quite diverse. They include managers, computer operators, database managers, accountants, salespeople, marketing representatives, office personnel, educators, mechanics and equipment maintenance workers, lab technicians (soil, crop, etc.), animal-health technicians (paravets), biotechnicians, irrigation technologists, vineyard-winery technicians and managers, product buyers, inspectors, quality-control technicians, pest control applicators, agronomists, animal nutritionists, and research assistants, to name just a few.

These jobs – as with most jobs today – will be filled by people with more years of education than in the past. And after they graduate, they can expect to spend at least three to six months in on-the-job training, depending on the individual and the job.

One occupation making an enormous impact on farm production today is that of farm manager. Since United States farmers operate as free, independent business managers, they must make vital decisions on production methods and cost outlays. Agricultural output is becoming less a result of natural factors and more a matter of assembling cost-effective technology, making calculated economic decisions, and applying them through effective management programs. Farm-management specialists increasingly develop this key information and guide farmers on alternative production methods using various technologies.

As the workforce changes – with the entry of more women, older people, people who speak English as a second language, and handicapped people – employers are finding it necessary to provide special training to increase social understanding of other cultures and personal perspectives.

Working group member Gary Varrella, curriculum development specialist with the University of California at Davis, offered the example of the rapidly changing population of the western and southwestern United States. More Hispanics, Southeast Asians, and women are entering agriculture at all levels in California. In addition, more people with physical and mental handicaps are becoming independent and seeking productive work in the field of agribusiness.

He pointed out that managers and directors of farm enterprises must become more sensitive to these people and their history and backgrounds, and become more effective managers of all personnel.

> *In my experience, this is not a difficult task, once misconceptions and unacceptable attitudes are dealt with (whether it be toward the handicapped, women, or minorities). More important, qualified minorities must be recruited, trained, and given opportunities to progress up the ladder of promotion. This also places a burden on the education system to provide opportunities for all students to grow and advance through their education and training.*

Personal and Job Skills

In the next decade, producers must be better prepared to recognize and solve problems and to work with highly skilled technical representatives. Costs and prices will continue to swell, and business management skills will become increasingly critical not only for farmers, but for the galaxy of industries that serve and support farmers.

Taking advantage of the opportunities that exist in agribusiness will require the mastery of basic skills and a knowledge of how to apply these skills to solve real, practical, and technical problems.

General skills – both academic and employee characteristics – needed by entry-level agribusiness employees are similar to those needed in most other occupational areas. They include reading on a twelfth-grade level; an ability to communicate effectively in both written and spoken form; high school math, science, and economics; typing; and an understanding of computer use. In addition, employees who want to succeed in their careers need the personal characteristics of a good work attitude and work ethic; an awareness of safety procedures and environmental issues; stress management; and a willingness to grow and change along with the industry. Previous experience with agriculture is a definite advantage.

Specific jobs may require additional skills. Someone working as a farm-equipment salesperson needs strong skills in oral communication and math, plus a detailed understanding of mechanics and the applications of the specific machinery being sold. A data processor for a large farm corporation needs accounting, computer management and programming, written communications skills, and a knowledge of agricultural subject matter. Other occupations may require laboratory techniques, chemistry, manual dexterity, or personnel management skills.

Equipment and Materials

In the next decade, employees in the agribusiness industry will need to know how to use much more sophisticated technical equipment. In pre-technical agribusiness days, 16-year-old farm youths may have been an asset when they drove the tractor and four-bottom plow around the field. Today a 16-year-old who also operates a computer and excels in science and algebra is an asset.

Employees in agribusiness routinely will need to know how to operate computers for word processing as well as data acquisition and interpretation. In addition, many occupations will require competency in laboratory techniques and with electronic instruments and devices, communications equipment, testing equipment, sophisticated mechanical machinery, and automated office machinery Most employees will need cross-training on equipment so they are competent to handle multiple tasks.

Publications

What may well be increasing at the fastest pace in agribusiness is literature about the industry. Volumes of reports, statistics, and opinions are produced each year, tracking the rise and fall of agriculture in the United States and throughout the world.

From the flood of available material, working group members cited several sources as good background to the educational needs of agribusiness employees and the changing employee population. These include the article, "Agribusiness Management Aptitude and Skills Survey," by Kerry K. Litzenberg of *Agricultural Economics* and Vernon E. Schneider of Texas A&M University, and the book, *Positioning Agriculture for the 1990s, a New Decade of Change*, from the National Planning Association. The 1988 report, "Understanding Agriculture: New Directions for Education," by the National Research Council, also was cited as an important resource. National FFA Organization publications and literature produced by other agriculture-related groups were suggested as sources of current information.

Summary of Key Issues To Address

1. The long-term negative image of vocational-technical programs as narrow training for job-specific occupations must be overcome, and the diversity of agribusiness occupations must be emphasized. Encouragement should be given to educators to open career options, not to close them. Emphasis should be put on overall education with a general core of knowledge, and transferable skills needed for the industry.

2. The curricula of vocational-technical education programs need to address work ethics/work attitudes, interpersonal skills, and self-management.

3. Elementary school skills – math, science, and reading – need to be strengthened to provide a stronger foundation for more advanced learning in higher grades.

4. High school students should be encouraged to take as many higher-level applied math and science courses as possible.

5. Communication skills – as basic as the ability to give and follow written and oral directions – need to be emphasized. Study of a second language is encouraged and may be essential in some geographic locations.

6. Agricultural vocational-technical courses must be kept current with technology by providing continued financial support and more opportunities for inservice programs for agricultural educators.

7. Industry and education need to cooperate in developing competency-based, standardized curricula where applicable, finding out what employers and industry need, setting standards of competencies, and establishing tests to confirm competencies learned in education programs.

8. Industry can help introduce the leading edge of technology to vocational-technical education teachers by inviting them to attend industry and trade conventions, meetings, and seminars. Donation of current equipment is another way industry can help.

9. Manufacturers should be encouraged to help vocational-technical education programs by opening their training schools to vocational-technical instructors.

10. Schools should follow up on student job placements to determine their students' success rate.

11. Employers need to be encouraged to promote greater understanding among their personnel – a heightened sensitivity to each worker's culture, job, and special needs. In the course of doing business, diverse groups need communicate with each other, so common understanding is necessary.

12. Continuing education materials need to be developed, especially in the field of business and economics.

13. Academic credit should be given toward high school graduation for some vocational-technical applied math, economic, and science courses.

14. Sequential curricula between education levels need to be provided. There should be a logical progression of courses from the secondary to post-secondary to community college to four-year university programs.

15. Cooperative education programs between agricultural businesses and educational institutions must be encouraged.

16. Students and employees should receive cross-training in the use of more than one type of equipment.

17. Career awareness programs need to be introduced in elementary schools to acquaint students at an early age with the worldwide opportunities of agribusiness so they can prepare themselves with adequate math and science courses.

18. Partnerships between trade associations and vocational-technical education facilities must be encouraged.

Section II: Chemistry-Based Technology

Introduction

For too many years chemistry has been regarded as akin to witchcraft and magic. For many reasons, including the general public's lack of knowledge about chemistry and the "I'm-not-a-math-and-science-person" misconception, careers in chemistry have not been popular among students.

Meanwhile, the United States continues to fall behind competitively in the world marketplace. To combat this deficit, we – the educators, businesspeople, industrial leaders, workers, and students – must place a new focus on the basics in math, science, and communication. Then we must persuade our young people to apply the knowledge effectively by filling the jobs that make us more competitive in today's technological world.

Right now in the United States thousands of jobs remain unfilled – in chemistry and hundreds of other occupations as well. The future of the chemical industry, especially in research and development of new or improved products and applications, depends on the availability of qualified chemistry-based technicians. The competition for educated workers in chemistry and other industries is, and will remain, intense. To meet this demand for workers, industry needs to create chemistry awareness and recruit interested students at a young age.

Business and industry representatives continue to reinforce how crucial is the need for early education in basic math and science. They emphasize that it is essential that applications skills be taught early and be reinforced throughout students' education.

All members of the working group, whether vocational-technical educator, manufacturing CEO, association head, businessperson, or chemistry-based technician speaking from on-the-job experience, expressed deep concern over the education of today's young people. They lamented the lack of math skills, the absence of science exposure, the poor quality of communication and reading skills, and the lack of a work ethic. All said that improving these basics is a prerequisite for a positive future. Meanwhile, efforts are being made to implement high-quality, industry- responsive, vocational-technical education programs. The jobs exist. Lucrative, rewarding careers are available. The big questions is: How best can we motivate and educate the people who will fill those jobs so we may provide industry with the competent personnel necessary for the future?

The Role of Chemistry-Based Technology in the U.S. Economy

The United States faces a national problem: maintaining its edge in an increasingly competitive global marketplace. We need to work harder to increase productivity and efficiency to challenge the foreign competition that now affects everything we do. What's more, the nation's workforce must be better matched to the work that needs to be done.

Education is a major part of the solution. Effective education can provide the foundation for successful competition at home and abroad. American employers need educated, well-prepared people to fill the thousands of technical positions that exist. A common complaint from employers is that too much time must be spent training employees, leaving too little time devoted to problem solving in industrial research and development. In the occupation of chemistry-based technician, this educational deficiency is readily apparent.

Some foreign countries have a large pool of highly skilled and specially educated chemistry-based technicians which gives these nations an edge in the global marketplace. Due to the shortage of qualified chemistry-based technicians in this country, some United States companies have considered recruiting chemistry-based technicians from abroad. These foreign technicians must meet required standards and possess well-defined qualifications for certification in their own countries; therefore, American employers have a good idea of what they are buying when they hire foreign graduates. No such certainty exists with our own graduates.

The United States must develop strategies to increase the number of people who have appropriate knowledge and skills to enter the technical workforce. We must employ whatever resources are necessary to ensure our competitive posture in the twenty-first century.

Defining "Chemistry-Based Technology"

Today's chemistry-based technicians perform a wide variety of sophisticated tasks in many settings. Technicians synthesize compounds, analyze chemical samples, test products, develop procedures, teach, and conduct research experiments. They collect scientific data gained through prescribed observation techniques, perform computation, then apply the laws and theories of science to the findings to come up with logical conclusions. They work in chemical-production facilities, the plants and laboratories of related industries, government and industrial research facilities, environmental laboratories, industrial plants, water-treatment plants, and many specialized areas.

The expanding role of the modern chemistry-based technician demands new skills, a higher level of scientific knowledge, and the flexibility to meet the challenge of rapidly changing technologies.

Because of this expanded role for chemistry-based technicians, working group members urged industry and professional/trade associations to work with educators to establish a core of unified qualifications and standards for the occupation, for both pre-employment and continuing education.

Some two-year college programs are based on the American Chemical Society's "ChemTeC" curriculum project of the early 1970s. While the competencies required in these programs were quite thorough for the time they were written, the programs now need to be updated. Indeed, a project to conduct a thorough review of today's needs is planned for Spring 1990.

Educational Requirements for the Chemistry-Based Technology Field

Elementary Education

As working group members studied the educational requirements to prepare well-qualified, career-oriented chemistry-based technicians, it became obvious that the process starts early – in elementary school.

One member said students need to decide by eighth grade if they want to pursue a career in science or technology. Only then can they take the four years of high school math and science needed as background for further chemistry education. Another member thought that instead of requiring an early decision, all students should be strongly encouraged to take math and science courses throughout the high-school years to keep their career options open in our increasingly technological world.

Science at this level should excite children about the processes of science, the thrill of discovery, and the challenges of problem solving. Elementary science should be taught on a daily, hands-on basis.

Secondary Education

As a minimum, students should have mastered high school freshman algebra. The ideal is two years of high school algebra and one year of geometry, plus some trigonometry.

At least two years of high school science, including laboratory courses, are needed. At least a year of chemistry and the prerequisite courses for it are necessary. Also, having biology, an additional year of chemistry, and physics is ideal. High-school science courses should emphasize realistic, practical applications of standard techniques used in modern laboratories. Laboratory courses should help students develop hands-on techniques and provide a knowledge of chemistry using appropriate instrumentation and equipment. In addition to providing practical skills, this will foster competence and self-confidence. These courses should give students experience with data collection, analysis, and interpretation, and an understanding of chemical principles.

While courses should be rigorous, mathematically based, and oriented toward mastering laboratory techniques, they should not necessarily be advanced placement or college preparation.

Courses meeting these criteria have been developed through the cooperative efforts of The Center for Occupational Research and Development and a consortium of state education agencies. Curricula have been written for high school courses in physics, communications, and mathematics which teach the material in an applied context. Similar courses, intended for the freshman or sophomore level, is being prepared for biology/chemistry.

This material also is designed to stimulate higher-order thinking. Many of the problems presented in these courses simulate problems encountered in the work place, and they do not have set answers. To respond to these problems, students must evaluate a number of facts and points of view, make inferences, and then choose a course of action. In some cases, a course of action may be taken without total success. The designers and developers of the materials recognize that rote learning is not adequate preparation for life, and that all students must develop abilities to solve problems and make decisions.

An example of this approach to teaching is the Principles of Technology, an applied physics course developed by a consortium of vocational agencies in 46 states and two Canadian provinces. During the field-test of the course materials in the late 1980s, significant gains in student interest and achievement were documented. During its second year of use, more than 25,000 students were enrolled in the course in more than 1,000 schools. It also is being used in industry to retrain workers.

Ken Chapman from the American Chemical Society stated that he believes today's typical high school chemistry and physics courses are designed as though all students will seek careers as university educated scientists or engineers. If more concentration were placed on laboratory work instead of theoretical presentations, that are often difficult to understand, high school science courses could produce students who would do equally well in standard college chemistry or chemistry-based technology programs.

Richard Sunberg, an employee of the Procter and Gamble Company who was recognized by the American Chemical Society as the 1989 Chemical Technician of the Year, noted that in the past many potentially excellent student candidates were eliminated because of weak math-computation skills. Fortunately, modern technology has come to the rescue with the advent of inexpensive but powerful hand-held calculators and computers. Sunberg used the analogy that to exclude all potentially excellent chemistry-based technicians because of poor math-computation skills is akin to excluding all scholars who cannot read without eyeglasses. The student with poor eyesight can never learn to see better without a device, but a poor math student armed with a calculator will improve dramatically in math calculations.

To refine the point, however, working group members Elizabeth Singleton and Harry Hajian pointed out that while calculators help people perform calculations faster and reduce the need for rote memorization, the machines cannot formulate the math concepts – people must do that, and math reasoning is a necessary skill.

> *"The modern chemistry-based technician must understand what he or she is doing; otherwise, poor input results in poor output,"*

Ms. Singleton said. She added that,

> *studies have shown that success in chemistry courses correlates directly with math skills. The old pair-of-hands technician who knew little math or chemistry could be trained to input numbers on a calculator and perform operations. Employers today want more than that. They want an understanding of these skills.*

Other non-science high school courses necessary for preparation as a chemistry-based technician also must emphasize both oral and written communications. Social sciences are also helpful.

While most entry-level positions now specify two years of college chemistry, etc., a few specialized secondary programs are producing employable graduates. One of these is Trezevant Vocational Technical Center in Memphis, Tennessee.

Diane Jernigan, director of the industrial chemistry vocational-technical education program at Trezevant Vocational Technical Center, knows firsthand what her students will face on the job. She previously worked in quality-control laboratories for two years and in university-level biochemical research for six years. She is determined that students who graduate from the Trezevant program will be prepared in math, chemistry, general science, and hands-on laboratory experience. These graduates will be able to obtain employment immediately after high school. Many continue their science education in college at their employers' expense.

Through Mrs. Jernigan's tireless efforts, the program at Trezevant includes a curriculum based on "what students need to be taught to make them useful employees for industry." Representatives from eight companies that use chemistry-based technicians sit on an advisory panel for the program. The result is a three-year curriculum packed with math and science, for which the students are given academic credits toward a high school diploma, and direct, hands-on laboratory experience. Students in the program spend a half day in the technical center and a half day in the high school, where they study English and other academic subjects.

Professor Harry Hajian cautioned that secondary programs must maintain a judicious balance between the technical aspects of such a curriculum and the liberal and fine arts aspects of schooling that help to educate a person for living a complete, well-rounded life.

Student training in the Trezevant program saves employers training time and money. For example, a two month industrial training period for one graduate was reduced to two days at a large pharmaceutical firm when it was realized that she understood and could use basic laboratory equipment.

Some of the math taught in the Trezevant industrial chemistry program is remedial, according to Mrs. Jernigan.

> *We give the students a pre-test and a post-test in math. The difference is amazing. We repeatedly find that students who first enter the program cannot do some of the basic sixth-grade math, such as*

fractions and word problems. Chemistry-based technicians need to be able to do both in the laboratory every day. What we are finding is that our community's students are sorely lacking in understanding basic mathematics. Much of our first year is spent bringing students up to speed, using individualized math instruction with practical application.

No matter what some educators say, some rote memory is important to establish a sound foundation for later math skills. It is equally important to understand how to apply math computation skills in word problems, and not just one or two problems stuck at the bottom of the page. Students must start learning from the first grade that not all math is presented as numbers printed on a page. Real math is being able to decide what needs to be done to find a solution to a problem when you are presented with a set of circumstances.

Mrs. Jernigan is equally outspoken on the need for exposing young students to science. "Television has been a major hindrance to science education in this country," she said.

On the other hand, it could have been a major learning tool. Much false scientific information has been passed along, and it will be hard to undo that misinformation. Instead of the Mr. Ed talking-horse or Incredible Hulk magic-potion type of television programs, children would benefit from interesting and instructional television based on scientific fact. They need to be taught why things happen the way they do, not the magic wand, vampire type of science fiction.

Setting up the Trezevant secondary program was not easy. The cost was high—about $100,000, even though some of the equipment was donated by private industry. Contrary to what other working group members from college-level educational institutions expressed, Mrs. Jernigan is not frustrated by receiving outdated equipment. "Analog equipment is much better for teaching than the newer digital equipment. If students learn how to use the analog equipment, digital is a snap. By learning on less automated equipment, students must do more of the work; they must understand better the principles of how things work," she said. Industry donations of lab supplies help keep program costs manageable.

The first problem in setting up the program was that no standardized secondary curriculum existed. Developing that curriculum took considerable effort involving both industry and academic representatives, and coordination with the academic high school curriculum.

Another hurdle was, and still is, the image of vocational-technical education programs as dumping grounds for students who cannot succeed in regular college-bound academic programs or those who have behavior problems. Parents and guidance counselors are reluctant to guide students into a vocational-technical program because they do not perceive it as a success option. The opposite, according to Mrs. Jernigan, occurs in the high-tech magnet schools for university-bound students. In Memphis, "students and parents stand in line for days to compete for available spaces in these schools," she said.

Both secondary and post-secondary, two-year-program students who opt for a career in chemistry usually are directed toward professional careers requiring advanced degrees. Many of the so-called "chemistry-based technology" post-secondary programs are designed for students who will transfer to another institution to continue their education, rather than graduating to the workforce with a two-year technical degree. Other programs are so narrowly focused and job-specific or local-industry-specific that their students lack flexibility, versatility, and the academic foundations necessary for lifelong learning and mobility.

What many parents and guidance counselors fail to realize is that only about one-fourth of all high school graduates go on to a four-year college, and that approximately one-sixth of all students who enter a four-year university-level program persist full time for four years. These figures, compiled by the National Center for Education Statistics, indicate that a large proportion of students really should not be considered university-bound in the first place. Several working group members suggested that these students' interests might be retained and their chances at further education enhanced, if the European tracking method was to be adopted in this country. The three tracks consist of university-bound, which includes only about 3 to 5 percent of the students; technical, such as engineering and technicians; and crafts or trades, which covers auto mechanics, construction, home economics, and numerous others.

Another problem that directors of the Trezevant vocational-technical industrial chemistry program face is the public's lack of knowledge about the chemical industry. General ignorance of the chemical industry makes a chemistry-based technician career a remote choice for students.

Most of the problems facing the secondary program at Trezevant are typical of the problems facing all vocational-technical education programs at both high school and college levels.

Working group members said that despite the isolated examples of success in the Trezevant high school program, the more frequent situation is that many mature, employed technicians who began their careers directly out of high school and were trained on the job, are under increasing pressure to return to school to complete higher level math and science requirements.

Most working group members felt that a combination of high school and post-secondary programs, often referred to as a 2 + 2 combination, provides an excellent educational background for employment as a chemistry-based technician.

In reality, the current education for chemistry-based technicians is primarily post-secondary, whether through vocational-technical programs, two-year associate degree programs, or two to four years of university science programs. All of these options ideally assume previous high school preparation with strengths in science and math. Students who come from vocational-technical or general education high school often need a preliminary year of remediation.

A model chemical technology program should be devised which emphasizes the essentials for the technician who knows he or she is going to go straight to industry.

Roger F. Bartholomew, Ph.D.
Research Associate in Chemistry
Corning Incorporated
Corning, New York

Beyond High School

Most entry-level jobs as a chemistry-based technician require a minimum of two years of college-level math, chemistry, and other sciences. The best educational sequence, according to one working group member, would be to have strong foundations in math, science, and communications on the secondary level; specific field education, such as chemistry technology on the post-secondary level; and specialized career development, such as analytical chemistry or polymer technology, in continuing courses taught by the employer or a college, university, professional society, vendor, or industry.

The amount of post-secondary education required for a job as a chemistry-based technician remains controversial. One view is that in the near future it is unlikely anyone will be hired for a position as a chemistry-based technician with less than a two-year associate's degree. This school of thought holds that many chemistry-based technicians with a two-year degree will use industry-paid education programs to complete the requirements for a bachelor's degree through night school and continuing education courses.

The other view holds that chemistry-based technicians with associate degrees are well-trained and educated, and that they are performing as well as or better than some Bachelor of Science (B.S.) degree chemists in the fields of quality control and research and development. A few companies have prejudices against hiring chemistry-based technicians with B.S. degrees. These employers express the opinion that the extra college credits provide little additional technical expertise and that B.S. degree chemists who work as chemistry-based technicians (rather than as assistant scientists) might perceive themselves as failures, affecting their job attitude.

The American Chemical Society (ACS) recognizes that the B.S. degree chemist from an ACS-approved chemistry program is a professional and should not be considered a technician.

All chemistry-based technicians increasingly will need continuing education once they are on the job. The post-secondary institutions identified as the major educators for chemistry-based technicians are community colleges and technical colleges. Those that specialize in this field include the Houston Community College, the Texas State Technical Institute System; the Community College of Rhode Island (CCRI); the University of Cincinnati's College of Applied Science; Cincinnati Technical College; and the Industrial Laboratory Technology program at the University of Cincinnati's Raymond Walters College.

The Community College of Rhode Island is one of the few remaining colleges that still adheres to the ACS

ChemTeC version of programs in chemistry-based technician education. Professor Harry Hajian initiated the chemical technology program there in 1966, funded by the Vocational Education Act of 1963.

From 1970 through 1972, Professor Hajian joined the American Chemical Society's ChemTeC project at the University of California at Berkeley and helped develop instructional materials for chemistry-based technician programs. Programs using these materials were introduced over the next few years at 12 pilot schools throughout the country.

The message we want to get out to students today is that they shouldn't be afraid to go into sciences — because of computers it is not difficult. You will need reasonable intelligence and a good attitude.

Richard J. Sunberg
Chemical Laboratory Technician
Procter & Gamble Company
Awardee: National Technician of the Year, 1989
American Chemical Society

The Community College of Rhode Island program was, and still is, highly successful. Because of its success, the CCRI program is used as a model in establishing other programs. Professor Hajian said CCRI graduates are satisfying employers with their job performance. He attributes the program's success to emphasis on lab-based teaching. The most important element in these programs is practical, industry-relevant laboratory experience and instrumentation exposure, plus the fundamental chemistry course work.

The number of graduates of these programs is small, however. So the chief sources of currently employed chemistry-based technicians are students who begin but do not complete university chemistry and chemical engineering programs, and students from other related science programs that require at least two years of college-level chemistry: biology, medical technology, pre-med, or science teaching.

At most two-year colleges, the main focus is on the traditional education/employment path — high school to college to job. This does not always meet the special needs of the chemical industry's nontraditional students — those making career changes or re-entering the workforce, for example.

Most college chemistry-based technician programs have a strong resemblance to the traditional chemistry major undergraduate program. Even when a two-year program is called "chemical technology" and describes a comprehensive program of study to prepare chemistry-based technicians, the flavor is more often a junior B.S. chemistry program than that of an independent program. These chemistry programs usually do not meet the specific needs of employed students. This problem sometimes is handled poorly even in programs designed jointly between employers and colleges, since the curriculum designers have difficulty avoiding the influences of their own previous college experiences.

Academic education requirements, the universal problem of recruiting students for chemistry study, and the need for well-equipped laboratories to prepare chemistry-based technicians have deterred the establishment of private specialty schools focusing on the training of this specific occupational group. The cost of programs for educating chemistry-based technicians is high: enrollments are low, and the necessary facilities, equipment, and instruments are expensive.

Chemistry-based technicians, as the offensive line players of the chemistry team, should have training that complements, rather than, replicates that of the quarterbacking chemist.

Kenneth M. Chapman
Education Division
American Chemical Society

In recent years there has been a steady increase in the job requirements for technicians, as evidenced by the steady rise in knowledge and skill levels for new hires. Employers want more varied skills from chemistry-based technicians. The old-style "pair of hands" technician has been replaced by automation of routine tasks. Now technicians must be able to supervise and program the robots, and interpret the results of analyses and experiments.

Continuing Education

Demands on chemistry-based technicians are increasing, especially in the areas of sophisticated instrumentation, computer-interfaced equipment, use of robotics, and high-technology industrial applications, such as biological engineering.

Technicians who want to advance in their career must, like scientists, be prepared for lifelong learning. Continuing education programs are needed to provide chemistry-based technicians with opportunities to sharpen their skills, increase their knowledge, and pursue independent learning.

Lester H. Wittenberg, a representative of the American Institute of Chemical Engineers Center for Chemical Process Safety, specified safety education as an example. He mentioned the increasing pressure for process industry plants to operate more economically while ensuring the safety of employees, neighbors, and the environment. Experts in human resources indicate that task instruction is the single most important tool for good, safe job performance. The Center has identified safety training and on-the-job safety performance as one of the 12 key components of any chemical-process safety-management program. Technicians specifically trained in the fundamentals of safe process operations and equipment also make good candidates for additional training in facility-specific topics.

Cooperative Education

Cooperative education should be used extensively to give students more exposure to instruments and procedures that may not be available in the school or within the expertise of the faculty. It is unreasonable to expect colleges to find the funding necessary to provide their students with experiences on all the modern instruments found in the typical employer's laboratory.

Elizabeth Singleton, an educator responsible for the chemical technology program at Houston Community College System, pointed out that

> *No simulated work environment can substitute for the real thing. One week on the job gives a student as much laboratory time as a full semester in a traditional chemistry course. Cooperative programs allow companies to evaluate the candidate on the job while the course provides students with practical experience and exposure to a career as a chemistry-based technician.*

One must be aware that for the cooperative experience to be meaningful, the work must be valid and the student must be a productive member of the working team; however, because of the worker shortage and because project-specific training is such an expensive investment for a company, students who have the skill to perform the needed tasks often are hired as full-time, permanent employees before completing the full course of education. As a result, the traditional meaning of a cooperative program is distorted, loyalties are blurred, and the evaluation procedures are made more difficult because worker privacy laws often prevent companies from releasing evaluations to an outside party.

No formal apprenticeship training programs for chemistry-based technicians exist, at least in the field of laboratory technology. Some operator training may include such programs, although most operators are industry-prepared through progressive, company-specific courses.

Much of the detailed training for chemistry-based technicians is on-the-job, and it takes a good deal of time in some cases for technicians to become proficient. The key is the new employee's scientific background and ability to apply basic concepts to the specific job. Typically, employers expect a strong academic background before investing time and money in on-the-job training.

Safety

The consideration of minimum age restrictions for students handling hazardous materials is a concern in education programs. Every vocational-technical education program should provide education and training in basic safety issues, laboratory fires, toxic chemicals, protective clothing, and eye protection. Safety films and information are readily available from vendors specializing in safety equipment and clothing, and from others such as the National Safety Council, the American Chemical Society, and the American Society of Safety Engineers.

American Chemical Society based programs stress training for intelligent, informed, safe laboratory practices. "Right-to-Know" training and hazardous waste management procedures are an integral part of many college programs. In some programs, students may not proceed to the first laboratory course until they pass a hazard communication test after an introductory course. Nevertheless, many educational facilities are not operated as safely as possible. Educators have little control over college operational budgets and facilities management policies. This is a weakness in many education programs.

Students should know how to read and understand Material Safety Data

Sheet (MSDS) instructions for hazardous materials and how to use the personal protection specified on the label and in regular operating situations. Students may benefit from training with fire extinguishers that use materials such as carbon dioxide, and other equipment actually used to fight industrial fires. Exposure to highly toxic or acutely hazardous materials is not recommended; however, safe handling of these can be addressed better through subsequent on-the-job training.

Since the nature of these acutely hazardous materials varies widely, it would be difficult for vocational-technical education programs to prepare students for all specific projects. Most college-level programs try to integrate federal and state safety codes into the curriculum. Government regulations require that workers receive specific worksite and project training in addition to generic safety-awareness education. Industries are prepared to provide this training along with appropriate protection as the need arises.

Despite the fact that chemistry-based technicians must work with hazardous materials, they usually are safer in the laboratory than in their automobiles. Minimal handling of hazardous materials is generally good practice, but complete elimination of potential hazards is not only impractical, but unrealistic in education programs.

Instructional Materials

Few instructional materials are designed specifically for trainees, who need knowledge of traditionally advanced topics and techniques at a freshman/sophomore college level. The best of these is probably the *Modern Chemical Technology* series (Prentice-Hall publishers) developed for the American Chemical Society curriculum by Harry Hajian (Community College of Rhode Island) and Robert Pecsok (University of Hawaii), who have rewritten and updated the series.

Other educational materials available for chemistry-based technician training programs include the British Analytical Chemistry by Open Learning (ACOL) series, developed specifically for technicians following the Royal Society of Chemistry certification ladder (available in the United States through John Wiley publishers). Also useful are *Analytical Chemistry for Technicians* by John Kenkel (Lewis publishers), and *Chemistry Made Easy*, developed for Bayer technician/operator upgrade training in Germany (a new English translation of this book is available; however, the material is complex, branched-, programmed-learning in a difficult style).

There is a need to develop audio-visual materials to supplement print resources for pre-employment education, as well as print and audio-visual materials for continuing education in such specialized areas as polymer chemistry/technology and industrial chemical processes.

In general, there is a need for continuing education and training for technicians who work rotating shifts that require scheduling flexibility beyond the means of most traditional educational institutions. Technicians on the night shift or rotating-schedule shifts cannot attend regular day or night school classes. The traditional 16-week semester cannot provide continuity for workers on a rotating shift who must change work hours (7-3, 3-11, 11-7) every 7 to 10 days. Materials such as self-study guides and "open learning" systems, also known as "distance education," that involve partnerships between industry, colleges, and professional societies need to be developed in the United States.

Britain has excellent models for this through the Open University/Open Tech system, where standards are set by the Royal Society of Chemistry. With this system there is no central campus site. Instead, the national television service broadcasts lectures, and students can gain laboratory experience and tutorial help at the nearest technical college, which serves as a learning center. The program also is monitored by the Manpower Services Commission, equivalent to the U.S. Department of Labor.

Employment Opportunities

Whatever the specific title, jobs for chemistry-based technicians fall into two general categories: laboratory-related occupations (science-based) and operations personnel (engineering and engineering technology). There is some overlap; for example, research and development pilot plant and process development projects often require both science and engineering skills.

Wide Range of Jobs

Chemistry-based technicians include the traditional chemical technician, plus individuals working in biological fields, biotechnology, or materials science – anywhere the work requires a knowledge of chemistry and chemical laboratory skills.

Some allied occupations to laboratory chemistry-based technicians for graduates of some vocational-technical education programs are engineering assistants, plant operators, and maintenance mechanics in the process industries, which include manufacturers in many parts of the 2800 section of the Standard Industrial Classification (SIC) code.

Like the professionals they assist, chemistry-based technicians tend to be generalists at the entry level. The professional scientist usually does not get a degree in "resins chemistry" or "electronics materials chemistry"; both the professional scientist and the chemistry-based technician start with a foundation of generic knowledge and skills. Specialization comes with experience and advanced studies.

Future Needs

It is hard to predict how many chemistry-based technicians will be needed to fill industry demands over the next five to ten years. Dr. Roger F. Bartholomew, with the Research, Development, and Engineering Division of Corning Glass Works and past chairman of the American Chemical Society's Committee on Chemical Technician Activities, said his number one priority is finding out exactly how many chemical technicians industry and other users need.

Working group member Richard Sunberg offered the example of Procter and Gamble. Over 1,000 technicians are employed at its four technical centers. "We typically hire one technician for each new staff person hired. In recent years, Procter and Gamble hired between 50 to 100 new research and development staff per year."

In another example, offered by Elizabeth Singleton, the Shell Development Company in Houston, Texas — the research center for all Shell Oil and Chemical companies — employs about 700 chemistry-based technicians. The company experiences about a 5 to 10 percent turnover of technicians a year, with 75 new technicians hired last year. The Texas based Rohm & Haas Company plant employs about 350 chemistry-based technicians, has an 8 to 10 percent turnover annually, and hired about 30 new technicians last year.

Availability of jobs for people with vocational-technical chemistry education varies geographically and from employer to employer. Scientists and technicians often have very different interests and objectives. Some employers recognize these differences and use them constructively to create effective working teams. Other employers simply seek the most highly educated person they can find for a given position and endure high attrition rates and reduced efficiency.

With a shortage of workers in this field, employers seldom have the luxury of demanding specific qualifications. Employers set minimum standards, hope for better, bid against each other for associate degree chemical technology graduates, and sometimes resort to pirating employees from other companies. This often results in less-than-adequate personnel.

Another effect of the shortage of qualified full-time chemistry-based technicians is industry's increasing dependence on temporary employees. Such employees are, according to Dr. Bartholomew, used by industry as a buffer against inflation and overhead costs because employers are not required to pay medical coverage and other benefits.

Changing Workforce

In the past 15 years, approximately 60 percent of the jobs for chemistry-based technicians have been filled by women. This reflects a dramatic increase in the number of women entering the field since the mid-1970s.

Blacks are not represented in chemistry-related jobs at a level comparable to their proportion in the population. While the number of Blacks, Hispanics, and people who speak English as a second language who hold jobs as chemistry-based technicians has increased, but aggressive recruiting could attract many more. Too many of these people are dissuaded from science technology-related jobs at a young age — even in elementary school — by their lack of opportunity to learn appropriate math and science skills.

Working group member and educator Elizabeth Singleton observed that in the past five years in the Houston, Texas area more chemistry-based technician jobs have been filled by women, especially those re-entering the job market, Asian and Central American students, and older students making midlife career changes. For example, the average age of the current freshman class studying chemical technology at Houston Community College is mid-30s. The increase of these nontraditional students is magnified by the decrease in traditional students.

These changes in the workforce population present some new difficulties. There is a problem in training students who speak English as as second language (ESL) — their English classes do not cover technical terminology. While these students may pass their ESL classes, they have difficulty in applying literary English in the technical program and on the job. An increasing number of newly hired chemistry-based technicians, both immigrant and native born, need help with speaking and writing English effectively. One working group member said a leading cause of industrial accidents is miscommunicated or misinterpreted instructions.

Mature students who are changing careers may require remediation in basic skills. Many of these students have little or no high school math and science background or they have forgotten what they did learn so they become discouraged during the training period. These students also experience economic constraints at a time when they have growing families to support. Because of changing careers, they lose salary and benefits built up through seniority in previous jobs.

Personal and Job Skills

The job of chemistry-based technician is so complex and project-variable that no one list of academic skills and employee characteristics exists. United States industry has never agreed on a set of basic, standardized competencies, although Canada, England, and some other European countries have such industry standards. While the jobs of chemistry-based technicians offer a diversity of stimulating challenges, there is a core of information and skills that all such technicians should acquire. Specialty and project-specific skills and knowledge then can be added to these basics throughout the employee's working lifetime.

Among the many competencies a chemistry-based technician may need are: a knowledge of basic analytical techniques and methods of synthesis and separation; expertise with a variety of sophisticated instruments; proficiency in the use of computer hardware, software, and interface systems; and the ability to keep detailed records and write reports. Valuable training would include exposure to some specialized applications such as standard methods for materials testing or for some industries or biotechnological methods.

To move up the career ladder, technicians need additional skills in management, communication, and advanced knowledge of chemistry and specialized fields. Industry experts project major changes in skill requirements in the next five to ten years, especially a need for increased computer and robotics skills.

Among the specific skills – both academic and personal – needed to enter and advance through the field of chemistry-based technician are:

1. **Using chemistry and math effectively** – skillfully applying and maintaining current technical knowledge and using appropriate mathematical and statistical procedures; collecting and manipulating data with dependable results; designing experiments that test technical hypotheses; identifying and reporting unusual occurrences in an experiment; verifying results.

2. **Analyzing problems and interpreting data** – defining and assessing the scope, objectives, and details of a project; understanding the relevance of experiments to products and processes; using

resources to gather facts, analyze data, and draw conclusions; developing alternative approaches or conclusions; relating test results to relevant technology.

3. **Organizing work and meeting time objectives** – consistently following a job through to completion; achieving results on time; setting priorities, scheduling, and adjusting workload to meet new demands; designing good experiments; handling several activities concurrently; and reacting well under stress.

4. **Growing in the job** – keeping abreast of new technology; learning technologies relevant to specific projects; learning new techniques quickly; profiting from constructive criticism about job performance.

5. **Dealing with change** – changing gears readily; considering different approaches in a practical, realistic way; being willing to try something new.

6. **Expressing ideas and feelings openly and honestly to supervisors** – voicing opinions, offering new ideas, and discussing work with the boss; speaking up even when the majority feels differently; offering constructive feedback to a supervisor; questioning managerial decisions when necessary.

7. **Working effectively with others** – skillfully interacting with people at every level and of every personality, race, and sex; securing cooperation from others when necessary; helping others learn; working effectively as part of a team; confronting and resolving conflicts.

8. **Communicating** – sharing accomplishments, observations, and results; writing and speaking clearly and persuasively; adapting information to the needs of the listener; using communication aids effectively; listening well.

9. **Striving to do good work** – doing the best job possible; showing concern for safety; setting a good example; recognizing opportunities; being on time; and respecting work rules.

10. **Taking the initiative** – taking charge and seeking solutions; initiating and experimenting; handling special problems independently; implementing work according to guidelines; accepting decision-making responsibility; seeking additional responsibility; asking for help when appropriate.

11. **Being creative** – suggesting solutions to problems; handling unusual tasks with creativity; perceiving what modifications are needed in an experiment; adapting processes and systems; using experience to draw analogies.

12. **Working well with laboratory or pilot plant systems** – understanding experimental systems and processes and how they affect operations; combining experimental equipment components; applying basic technology to experiments; noticing, understanding, diagnosing, and troubleshooting malfunctions in instruments or procedures; exercising care handling instruments, experimental equipment, and animals; exhibiting manual dexterity and coordination.

In the past, technicians were not as involved in project decisions and team commitment as they are today. As the workers closest to the data generation, today's technicians have increasing impact on major project direction and the decision-making processes. This additional responsibility will result in technicians being viewed more as professionals than as mere workers.

Equipment and Materials

In addition to specialized equipment that is project-specific, most entry-level chemistry-based technicians must be able to learn about and operate a wide range of basic equipment. This includes valves, pumps, compressors, and analytical instruments, such as gas chromatographs, visible and ultraviolet spectrophotometers, infrared spectrometers, atomic absorption/flame emission instruments, mass spectrometers, nuclear magnetic spectrometers, high-performance liquid chromatographs, as well as computers and computer interface equipment. Technicians also must be capable of learning how to use more sophisticated instruments with minimum additional training time.

The increasing costs of sophisticated, state-of-the-art equipment, including maintenance and repair, puts a serious constraint on the ability of chemical-technology education programs to provide appropriate training. Equipment donated by industry often is obsolete and in poor repair. Training in the new combined techniques, e.g., coupled gas chromatograph-mass spectrometers and microprocessor- controlled instrumentation, is often beyond the means of education programs.

Since many entry-level chemistry-based technicians are dropouts from four-year programs where working with instruments is a senior- or graduate-level course, they need on-the-job training in basic operational skills.

In American Chemical Society-model programs, students begin such training in the second week of class. Because of this, many companies will credit ACS-model program graduates with two years of job experience upon hiring. This is reflected both in responsibilities and salary, an indication of the economic value to industry of specialized training programs.

Publications

With the exception of American Chemical Society (ACS) publications, the subject of chemistry-based technician education has not been adequately addressed in the United States. The main English-language source of information is the British Royal Society of Chemistry journals, including *Chemistry in Britain*.

Good background reading includes a paper by John Kenkel soon to be published in *The Journal of College Science Teaching* and several short articles from *The Distillate*, an ACS newsletter for two-year college chemistry teachers. The following resources also may prove useful:

- Kenkel, J.V. "A Community College Program for the Training of Technicians," *Journal of Chemical Education*, Vol. 63 (July 1986), pp. 614-615.

- "Human Capital," *Business Week*, September 19, 1988. (While the article is not specific to chemistry-based technicians, it is directly applicable to this segment of the workforce, in that it gives a comprehensive view of problems and some solutions.)

- "Future Shock, The American Workforce in the Year 2000," *AACJC* (American Association of Community and Junior Colleges) *Journal*, February/March 1987.
- Harris, Louis, "2001: The World Our Students Will Enter," *The Innovator*, League for Innovation in the Community College, 1988.

Summary of Key Issues to Address

The key to survival of the American chemical industry in the global marketplace lies in the translation of innovative ideas into useful products, processes, and services. A primary transfer agent in this process is the chemistry-based technician, a vital human link between innovation and application.

Consequently there is a critical need to attract new people to the occupation, and to develop educational opportunities that ensure both entry-level competence and the tools for lifelong career development. Such goals will require the combined efforts of industry, education, government, and professional societies. To this end the following are needed:

1. **Marketing strategies that will recruit new technicians and increase public awareness of their important contribution to society.**

We must tap the pool of high school general education students, especially those who have an interest in science and technology, but who are discouraged by the long (up to eight years for M.S. and Ph.D. degrees), expensive pre-employment education required for professional chemists. We need to identify technical education as a promising career track. Teachers, counselors, and parents often are unaware of the many rewarding careers available in chemical technology, or consider them the refuge of failed doctors, engineers, and scientists. We must help all concerned to understand that industry needs first-rate technicians, not second-rate chemists.

Rarely are professional and technician positions in chemistry advertised in the classified employment ads in newspapers. Companies prefer to recruit directly from colleges, use employment agencies, or advertise in trade and professional journals. Few high school students and counselors subscribe to *Chemical & Engineering News*. For them, the classified section of the local newspaper is a major source of career information that could be better used by the industry.

The class of the year 2000 has entered second grade. Members of the class are able to read, write, and do simple math. How many already have decided that they are not interested in science? Science should be introduced at the third grade level as an experimental, action-oriented subject taught by a specialist, not a homeroom teacher.

2. **Models for competency-based education and training programs that provide up-to-date technical skills, a knowledge of basic chemical and other scientific principles, and**

the general education needed for career advancement.

Until the occupational categories are characterized and qualifications and standards for entry-level and advancement steps are defined and unified, effective curricula cannot be developed. The practice of designing narrow, job-specific programs to meet urgent hiring needs for local companies is inefficient and produces inflexible workers who need expensive retraining as technology changes. The "plastics technician" and "wastewater analyst" need the same core knowledge and skills, just as physicians learn medicine before specializing in open-heart surgery. Project-specific training should build on a set of foundation competencies.

3. **A definition of the roles of various constituencies in educating chemistry-based technicians.**

Increasingly, chemistry-based technicians are performing tasks that require higher skill levels (many of which previously were performed by B.S. degree holding chemists and engineers). Several options exist for educating these technicians. Programs can begin in high school and continue through a two-year college associate degree. An example is the four-year "2 + 2 Tech Prep" described by Dale Parnell of the American Association of Community and Junior Colleges: career cluster preparation in eleventh and twelfth grades with discipline specialization on the post-secondary level.

Another option is the "2 + 2" plan divided between a community college and a university, with the final goal a bachelor's degree in applied science or technology.

The Canadian option provides for two years of training for chemical technicians (general), with a third year of specialization as a chemical technologist – all provided at the community-college level.

There also must be a decision about whose job it is to provide continuing education – community colleges, universities, companies, professional societies, unions, or a consortia of these.

4. **Certification of occupational qualifications and educational standards.**

Is there a need for formal certification, either through government licensing or professional society accreditation, as a condition for practice? Would the informal process advocated by the American Institute of Chemists – similar to that used by the Board of Certified Safety Professionals and American Board of Industrial Hygiene – suffice? Or is certification of any kind too restrictive?

The American Chemical Society's task force on two-year college chemistry has appointed a subcommittee on chemical technology that has formed an approval program and process for chemistry technology programs in the United States. In early 1990 this proposal was near the end of the process for obtaining official American Chemical Society endorsement. Meanwhile, educational institutions can use a set of available guidelines to assess their existing ChemTech programs or to establish such programs.

5. **Funding to support development of effective programs. Money is needed to:**

   - Recruit students who will become the technicians of tomorrow;
   - Hire the personnel necessary to answer the questions raised above and design the curricula that will meet workforce goals;
   - Provide the facilities, equipment, and instructional materials essential for education and training; and
   - Ensure that academic faculty and training staff are prepared to manage learning for this special population.

   Seed money is critical if e[illegible]ment-driven educational s[illegible]ms are to escape the "Catch-22" equation:

   FEW STUDENTS* = LOW BUDGETS = POOR QUALITY = INADEQUATE JOB RECOGNITION = <u>NO</u> STUDENTS

** The "few students" can be attributed to the image that "chemistry is difficult," to competition for technical program students, to a lack of public awareness of chemistry-based technician careers, and to meager opportunities for the disadvantaged.*

6. **Surveys of employers to gather information on job markets, workforce demands, and educational needs for technicians in the next 10 years.**

7. **Creative, effective partnerships among all who recruit and educate technicians.**

   Clearly, the chemical industry and chemistry-based technicians need to become more involved in the education process. Several of the technician affiliate groups of the American Chemical Society now volunteer their services to local schools from kindergarten through college. Technicians in the ACS affiliate groups judge science fairs, work on science fair advisory boards, recruit judges, and conduct chemistry "magic" shows and science-enrichment programs. They lecture at local high schools and colleges on chemistry careers, serve on program advisory boards, conduct numerous tours of laboratory facilities for student groups, and arrange for the transfer of thousands of dollars of scientific equipment to schools and universities. Some volunteers provide inservice day programs for school teachers. Other companies provide summer training programs in industrial chemistry.

   More students need to be introduced to chemistry at the elementary level so they can decide whether they want to pursue a career in science. More volunteer efforts and more commitment from industry can help achieve this exposure early enough for interested students to take the four years of high school math and science needed to prepare for a degree in chemistry.

   One example of a highly effective promotion for chemistry careers was given by working group member Richard Sunberg. More than 2,600 elementary school children from 500 schools in Kentucky, Indiana, and Ohio tried to explain why raisins dance — or rise to the top and sink again — when dropped into a glass of carbonated soda. The contest was sponsored by the Technician Affiliate Group of the Cincinnati local section of the American Chemical Society as part of Science Week during the city's Bicentennial Celebration last fall. In a unique cooperative approach, Hardee's restaurants, which then featured the California Raisins in sales promotion activities, donated coloring sheets and hamburger coupons to all children who entered the contest, as well as a set of six California Raisin figurines to each of the five finalists. Kroger Food Stores supplied 500 boxes of raisins and 1,000 liters of its house brand lemon-lime soda for school demonstrations.

In Summation

As diverse as the fields of agribusiness and chemistry-based technology are, they share some common needs. Both are now or shortly will be faced with a shortage of qualified employees, while the number of new jobs will increase. Both depend on vocational-technical education programs to provide qualified workers to the field. Both require students entering vocational-technical education programs to have a solid academic background in oral and written communications, math, and science.

In the various occupations of both industries, employers are looking for employees with values in ethics, self-discipline, responsibility, decision-making, and interpersonal relations.

Representatives of both industries listed these actions that need to be taken:

1. Teach elementary school students to be competent in the basic skills of reading, writing, math, and science Encourage high school students to become proficient in oral and written communications, math, and science.
2. Recruit young people into the occupational fields, and increase public awareness of what these occupations contribute to society.
3. Enhance the image of vocational-technical education programs as a way to expand opportunities.
4. Keep vocational-technical instructors current with the industry by making it possible for them to attend conferences, trade shows, and association meetings, and by involving industry in the training of vocational-technical instructors.
5. Develop cooperative education programs.
6. Write sequential curricula for secondary and post-secondary vocational-technical education programs.
7. Develop models for competency-based education programs that provide up-to-date technical skills, a core of occupational knowledge, and

a general education needed for career advancement and lifelong learning.

8. Provide vocational-technical education facilities with adequate space, enough modern equipment of durable quality, adequate resources and reference materials, and teachers with current knowledge of the industry.

9. Cooperatively (employers and educators) develop a list of occupational competencies, and design methods of certification.

10. Develop affordable, accessible continuing-education materials.

11. Actively seek funding for recruitment, curriculum writing, facilities, teaching materials, equipment, and faculty.

12. Survey employers to gather information on job markets, human capital demands, and educational needs for the next 10 years.

13. Follow through on student placements and job performance.

To remain competitive in world markets, American business and industry must be productive and responsive to the demands of the market. To supply trained, skilled workers for business and industry, vocational-technical education programs must be responsive to the needs of business and industry. Through cooperation, those needs will be met. Meetings like these working groups, held under the auspices of the National Council on Vocational Education to explore the occupational competencies and needs of business and industry, are precisely the environment in which such cooperation can take root and grow.

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